Reducing NPR 7120.5D to Practice: Transitioning from Design Reviews to the SIR Hardware Review

Randall Taylor
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099
818-354-1865
Randall.L.Taylor@jpl.nasa.gov

Abstract— The Gravity Recovery And Interior Laboratory (GRAIL) mission was the first Jet Propulsion Laboratory (JPL) project initiated under NASA's revised rules for space flight project management, NPR 7120.5D, "NASA Space Flight Program and Project Management Requirements."[1] [2]

NASA selected GRAIL through a competitive Announcement of Opportunity process and funded its Phase B Preliminary Design effort. The team's first major milestone was a JPL institutional milestone, the Project Mission System Review (PMSR), which proved an excellent tune-up for the end-of-Phase-B NASA life-cycle review, the Preliminary Design Review (PDR). Building on JPL experience on the Prometheus and Juno projects, the team successfully organized for and conducted these reviews on an aggressive schedule.

For the Project Critical Design Review (CDR), lessons learned from the PDR and updated Standing Review Board (SRB) practices from the Agency were factored into the review preparation effort. Additionally, the review was held at the Principal Investigator's institution, the Massachusetts Institute of Technology, rather than at the project management center (JPL), which necessitated additional cross-country coordination steps.

The PMSR, PDR, and CDR were design reviews and largely paper-oriented. For the System Integration Review (SIR), the project needed to transition to a hardware review and deal with paper in a very different manner. While many of the practices employed for the design reviews were modified and retained (e.g., review preparation team, gate products management, pre-reviews, SRB coordination), the review agenda, presentation style, and slide templates were significantly changed. A key success factor concerned the handling of project "open paper," which was succinctly and effectively communicated to the SRB in presentations.

This paper provides a brief overview of the GRAIL mission and its project management challenges, provides a detailed description of project SIR preparation and execution activities, including positive and negative lessons learned, and identifies recommendations for future NASA (and non-NASA) project teams.

TABLE OF CONTENTS

1. INTRODUCTION

In December 2007, NASA competitively selected the Gravity Recovery And Interior Laboratory (GRAIL) mission under the Discovery Program for solar system exploration. As stated in the successful proposal, "GRAIL will precisely map the gravitational field of the Moon to reveal its internal structure 'from crust to core,' determine its thermal evolution, and extend this knowledge to other planets" [1]. Increasing knowledge of the far side of the Moon is particularly important because relatively little is known about it.

GRAIL will place twin spacecraft in a low-altitude, near-circular polar orbit around the Moon. It will perform high-precision range-rate measurements between the orbiters using a Ka-band payload. The spacecraft range-rate data (changes in separation distance between the orbiters), time-correlated by NASA's Deep Space Network, provides a direct measure of lunar gravity [2]. GRAIL will conduct science operations for approximately 82 days, which constitutes three mapping cycles.

There are six science investigations associated with the Science Phase, the first four of which are required for minimum mission success (the "science floor") and the

[1] 978-1-4244-7351-9/11/$26.00 ©2011 IEEE
[2] IEEEAC paper#1252, Version 1, Updated 2010:10:04

remainder to achieve full mission success (the baseline mission):

(1) Map the structure of the crust and lithosphere.

(2) Understand the Moon's asymmetric thermal evolution.

(3) Determine the subsurface structure of impact basins and the origin of mass concentrations (mascons).

(4) Ascertain the temporal evolution of crustal brecciation and magmatism.

(5) Constrain deep interior structure from tides.

(6) Place limits on the size of a possible lunar core [3].

GRAIL is led by the Principal Investigator (PI), Dr. Maria T. Zuber of the Massachusetts Institute of Technology (MIT), assisted by the Deputy PI, Dr. David Smith of MIT. JPL provides project management, systems engineering, safety and mission assurance, the science instruments (one per orbiter), mission design, mission operations and ground data system, and gravity science modeling and data analysis. NASA's Goddard Space Flight Center (GSFC) also performs gravity science modeling and data analysis. Lockheed Martin (LM) provides the twin spacecraft and performs assembly, test, and launch operations. United Launch Alliance (ULA) provides the Delta II Heavy launch vehicle and associated launch services, supporting NASA's Kennedy Space Center (KSC). Sally Ride Science conducts the education and public outreach program. Many subcontractors support the team. The Discovery Program Office at NASA's Marshall Space Flight Center (MSFC) is responsible for funding, technical direction, and surveillance of the project.

2. NASA Requirements for Project SIR

NASA Procedural Requirements (NPR) 7120.5D, "NASA Space Flight Program and Project Management Requirements," issued in March 2007 and revised in February 2010, establishes a project life cycle for both human and robotic missions, with specific project phases (see Figure 1). GRAIL is the first new-start JPL space flight project implemented under this NPR.

To pass from one life-cycle phase to the next, the project must complete specified gate products and control plans, perform internal reviews, support an independent review, and receive approval from a Decision Authority (DA) at a Key Decision Point (KDP). NPR 7120.5D specifies the requisite gate transition reviews, along with additional independent reviews to be conducted earlier in the applicable phase.

The Project SIR is a life-cycle gate transition review, defined in NPR 7120.5D as follows: "The SIR evaluates the readiness of the project to start flight system assembly, test, and launch operations. V&V plans, integration plans, and test plans are reviewed. Test articles (hardware/software), test facilities, support personnel, and test procedures are ready for testing and data acquisition, reduction, and control." [4]. The SIR is to be conducted at the end of Project Phase C (Final Design and Fabrication), using an independent NASA Standing Review Board (SRB). Because the SIR is a phase gate review, the NPR specifies gate products and control plans to be completed by the review. The results of the review are presented to the NASA Decision Authority (DA) at KDP D; the DA then approves or disapproves the project's proceeding into Phase D.

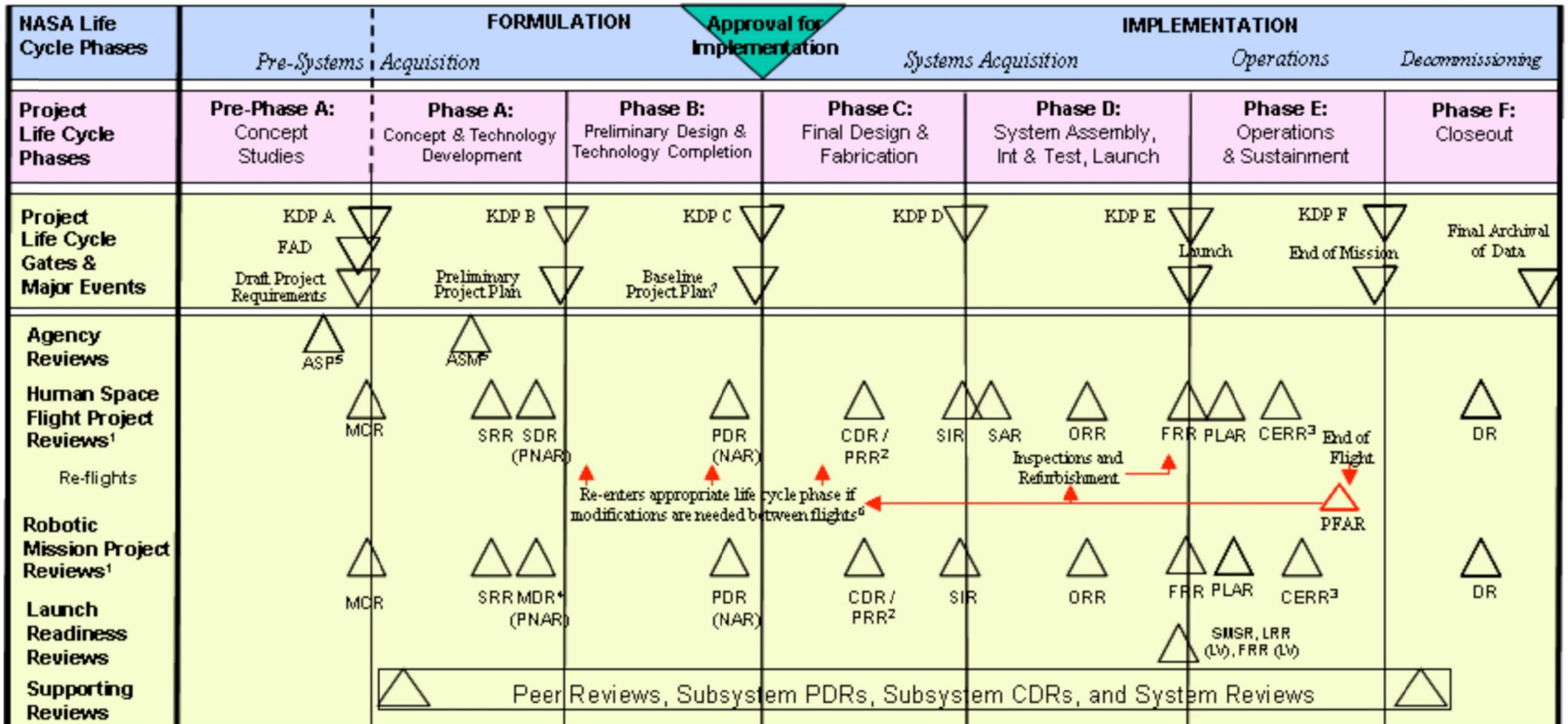
Additional guidance on the Project SIR is contained in NASA and JPL command media. NPR 7123.1, "NASA Systems Engineering Processes and Requirements," enumerates both entrance criteria for holding the review and success criteria for completing the review [5]. Additionally, the JPL "Institutional Project Review Plan" (IPRP) identifies the objectives, scope, and timing of the review, and it provides guidelines for generating the detailed review agenda [6]. Gate products for the Project SIR are defined in the JPL project life-cycle gate products list; these include both the NASA 7120.5D–required documents and JPL institutionally required ones [7].

3. Previous Experience: PMSR, PDR, CDR

Prior to beginning preparations for the SIR, the GRAIL team had gained experience—in some cases the hard way—from three previous independent reviews. Details of the review planning for the Project Mission System Review (PMSR) and the Project Preliminary Design Review (PDR) are contained in the 2008 IEEE paper, "Reducing NPR 7120.5D to Practice: Preparing for a Life-cycle Review" [8]. Information on the review preparation activities for the Project Critical Design Review (CDR) are contained in last year's IEEE paper, "Reducing NPR 7120.5D to Practice: Preparing for a Remote Site Life-cycle Review" [9].

Each review involved specific entrance criteria, gate products, and special topics reflecting the nature of the mission (e.g., science modeling approach) or then-present technical problems (e.g., reaction wheel development), as well as differing approaches to schedule risk assessment taken by the cognizant review board (JPL review board for PMSR, NASA SRB for PDR and CDR). For example, one of eight success criteria for the SIR is "Adequate integration plans and procedures are completed and approved for the near-term system integration, and plans and resources exist for timely delivery of the remainder" [10]. Consistent with that criterion, one of ten entrance criteria for the SIR is "Integration plans have been completed and approved." [11]

As discussed below, some review preparation techniques and tools worked well from inception, either as-is or with some fine tuning, whereas some others needed significant modification or had to be scuttled. A byword of an effective institutional or project review activity is "flexibility."



FOOTNOTES

1. Flexibility is allowed in the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan. These reviews are conducted by the project for the independent SRB. See Section 2.5 and Table 2-6.
2. PRR needed for multiple (≥4) system copies. Timing is notional.
3. CERRs are established at the discretion of Program Offices.
4. For robotic missions, the SRR and the MDR may be combined.
5. The ASP and ASM are Agency reviews, not life-cycle reviews.
6. Includes recertification, as required.
7. Project Plans are baselined at KDP C and are reviewed and updated as required, to ensure project content, cost, and budget remain consistent.

ACRONYMS

ASP—Acquisition Strategy Planning Meeting
ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
DR—Decommissioning Review
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
MCR—Mission Concept Review
MDR—Mission Definition Review
NAR—Non-Advocate Review
ORR—Operational Readiness Review
PDR—Preliminary Design Review
PFAR—Post-Flight Assessment Review
PLAR—Post-Launch Assessment Review
PNAR—Preliminary Non-Advocate Review
PRR—Production Readiness Review
SAR—System Acceptance Review
SDR—System Definition Review
SIR—System Integration Review
SMSR—Safety and Mission Success Review
SRR—System Requirements Review

Figure 1—The NASA Project Life Cycle

4. ORGANIZATION: ROLES AND RESPONSIBILITIES

For the SIR, GRAIL continued with the review team construct that was successfully employed for the previous independent life-cycle reviews. The review team was downsized a bit as compared to CDR, because the SIR was not conducted at a remote site. As discussed below, this greatly simplified the IT and logistics effort.

The project Review Captain (RC) led the review team and performed specific functions. The RC role was performed by the Project Acquisition Manager (the author). He was in charge of gate products and presentation materials instructions, guidelines, interpretations, and content review, receiving support from other team members and the Project Schedule Analyst. He supported the Project Manager in interactions with the SRB.

The Documentation Lead (DL) represented the institutional Documentation Services organization. She and her supporting staff were responsible for gate products and presentation materials formatting, editing, and production. She also served as the recorder for the SRB during the review week. The Information Systems Lead (ISL) role was performed by the project emeritus Information Management Engineer. She was responsible for the information technology system and equipment requirements at the home institution (JPL). Her supporting staff, including the Project Librarian and Configuration Management Engineer, implemented architecting of file formats and data repositories for gate products and presentation materials, established access privileges for project team members (including foreign persons), and transferred materials from the JPL repositories into the SRB repository. Because the SIR was held at Lockheed Martin (LM) in Denver, LM assigned an experienced IT specialist to coordinate on-site support. A new Logistics Lead was assigned for this review, one of the LM system engineers. He coordinated attendance, visitor access, conference rooms, parking, and miscellaneous support needs.

The team employed a refined version of the preparation schedule developed for the previous reviews to keep track of activities and to support the content providers on the project. The SIR Preparation Schedule is provided as Figure 2.

Preparation for the SIR involved six “threads” of activity. Pre-SIR reviews are discussed in Section 5, gate products in Section 6, presentation materials in Section 7, IT and logistics in Section 8, and SRB support in Section 9.

5. PRE-SIR REVIEWS

The team identified in Section 4 served in a support role to pre-SIR reviews, which reflected the major technical work activities since Project CDR, as well as some areas of emphasis identified by the SRB. The cognizant designers, product delivery engineers, test planners, and scientists performed the required activities, as explained below.

Pre-SIR reviews were conducted from December 2009 through June 2010. There were many peer reviews and some independent reviews, as summarized below:

Project Reviews—including verification and validation (V&V) and science modeling.

Payload Reviews—covering all instrument assemblies and the payload as a whole.

Spacecraft Reviews—covering all spacecraft hardware subsystems (starting with the Avionics Delta CDR in December 2009, and including independent assessment, PDR, and CDR for the newly added SoftRide launch loads attenuation system), flight software, testbeds, and integration and test.

Mission System Reviews—covering the Mission Operations System (MOS), Ground Data System (GDS), and mission design, via peer reviews, delivery reviews, an SRB-commissioned Staffing Review, and the MOS CDR.

The product of these reviews, and other requirements, design analyses, and unit-level tests, constituted the technical baseline for Project SIR. As further explained below, the project team worked very hard to close “open paper” prior to the SIR; this proved a key contributor to success at the review.

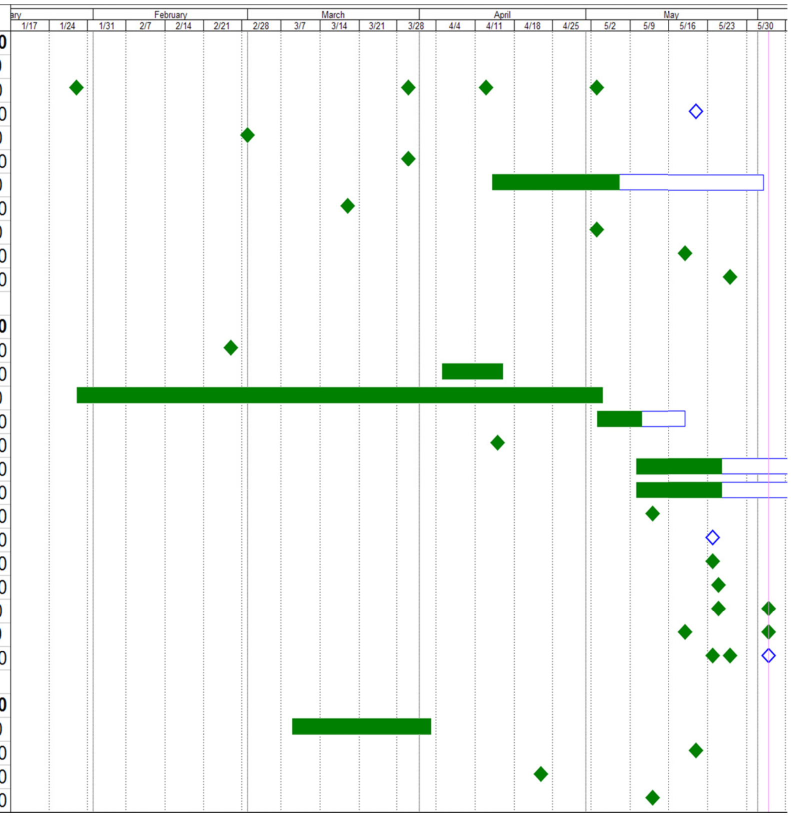
6. GATE PRODUCTS

As a phase transition review, Project SIR is subject to NPR 7120.5D gate products and control plans requirements. A few additional ones are implied in the NPR 7123.1 entrance criteria for the SIR. Projects will baseline their document deliverables during Phase A but must be aware that the Agency may add new requirements later (e.g., when GRAIL started, there was no requirement for an End of Mission Plan). Also, the sponsoring Mission Directorate may add new requirements (e.g., NASA’s Science Mission Directorate issued a new policy that required an Education and Public Outreach Implementation Plan).

The JPL Life-Cycle Gate Products List includes most (but not all) of the NASA-required documentation, as well as many institutionally required gate products. There are far fewer documents required for SIR than for Project CDR or for Project PDR (when the largest number of documents are due), and many SIR gate products are simply more mature versions of documents previously submitted. Following are some examples:

NASA gate products: First-time submittals are Preliminary Operations Handbook, Preliminary Systems Decommissioning/Disposal Plan, and Detailed Design Report (DDR). Most submittals are Baseline or Update versions of earlier deliverables (e.g., Baseline Missile

ID	Task Name	Start	Finish
1	**GRAIL**	**1/29/10**	**6/14/10**
2	**REVIEW BOARD ACTIVITIES**	**1/29/10**	**6/1/10**
3	CDR RFA closures submitted	1/29/10	5/3/10
8	SRB concurs on closures	5/21/10	5/21/10
9	Draft Terms of Reference (ToR) SIR Appendix	3/1/10	3/1/10
10	ToR Appendix accepted by SRB	3/30/10	3/30/10
11	ToR Appendix signed	4/14/10	6/1/10
12	Draft SIR Agenda (summary agenda)	3/19/10	3/19/10
13	SRB accepts Agenda	5/3/10	5/3/10
14	Draft documentation submission schedule	5/19/10	5/19/10
15	SRB accepts documentation schedule	5/27/10	5/27/10
16	SRB Kickoff Meeting support (if requested)		
17	**GATE PRODUCTS ACTIVITIES**	**1/29/10**	**6/11/10**
18	Assign SIR gate products	2/26/10	2/26/10
19	Issue drafting instructions	4/5/10	4/15/10
20	Clarify gate products content	1/29/10	5/3/10
21	Drafts to Documentation Services	5/3/10	5/18/10
22	Issue submittal/signature instructions	4/15/10	4/15/10
23	Submission of draft documents	5/10/10	6/10/10
24	Project review completed	5/10/10	6/10/10
25	CCBs completed	5/13/10	5/13/10
26	Documents signed	5/24/10	5/24/10
27	CADRe to IPAO	5/24/10	5/24/10
28	EVM data to IPAO	5/25/10	5/25/10
29	Cost/Schedule Assessment data to IPAO	5/25/10	6/3/10
32	Risk List to SRB	**5/19/10**	**6/3/10**
35	Gate products to SRB (in PBMA)	5/24/10	6/11/10
40	Gate products to SRB (CD) -- TBN		
41	**PRESENTATION SLIDES ACTIVITIES**	**3/9/10**	**6/14/10**
42	SIR key messages	3/9/10	4/2/10
43	SIR key messages update	5/21/10	5/21/10
44	Draft detailed SIR Agenda	4/23/10	4/23/10
45	Final detailed SIR Agenda	5/13/10	5/13/10
46	Presenters assigned	3/17/10	3/17/10
47	SIR Outline Review instructions	4/28/10	4/28/10
48	Outlines submittted	5/13/10	5/13/10
49	SIR Outline Review	5/12/10	5/13/10
50	Slides drafting instructions & template	5/20/10	5/27/10
51	Dry Run Slides Submitted	6/7/10	6/9/10
52	SIR Dry Run	6/7/10	6/9/10
53	SIR Dry Run Do-Over	6/10/10	6/10/10
54	Final slides submission instructions	6/7/10	6/7/10
55	Final slides submitted	6/10/10	6/10/10
56	QA check with Documentation	6/11/10	6/11/10
57	Slides to SRB (in PBMA)	6/14/10	6/14/10
58	Slides to SRB (CD)		
59	**SUPPORTING MATERIALS ACTIVITIES**		
60	Visualization completed		
61	Movie voiceover by PI	3/23/10	3/23/10
62	Movie completed		
63	Fact Sheet Updated	3/22/10	6/2/10
66	Shipping arrangements completed	3/1/10	4/12/10
67	**OTHER DOCUMENTATION**		
68	CSR (CD)	6/2/10	6/2/10
69	Inheritance Reviews (CD)	5/25/10	5/25/10
70	Gate Products (CD)	5/25/10	5/25/10
71	Project PDR (CD)	3/31/10	3/31/10
72	Pre-CDR Reviews (CD)	5/25/10	5/25/10
73	Project CDR (CD)	3/31/10	3/31/10
74	Pre-SIR Reviews (CD)		
75	Project SIR (CD)		
76	**SITE LOGISTICS ACTIVITIES**		
77	Conference room walkthrough	2/16/10	2/16/10
78	Conference Room Walkthrough (New Room)	3/16/10	3/16/10
79	ATLO/facilities tour walkthrough	2/16/10	2/16/10
80	Attendance policy	5/20/10	5/20/10
81	Equipment list completed	4/26/10	4/26/10
82	MeetingPlace reservation		
83	Set-up		



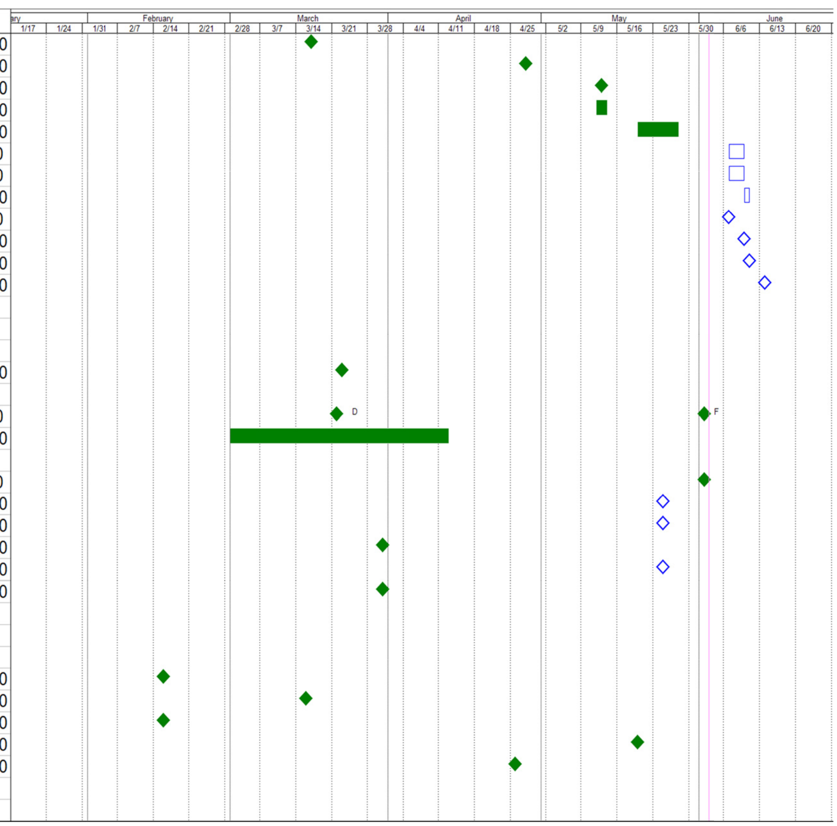


Figure 2—GRAIL SIR Preparation Schedule

System Prelaunch Safety Package, updated Cost Analysis Data Requirements). To meet the intent of a DDR without investing extensive labor hours into producing a highly formatted paper product, the project provided its Project CDR and Project SIR presentations as defining the project's detailed design. Lower-level details of course are embedded in the referenced design drawings, requirements database, etc.

NASA control plans (CPs): Only four CPs are due at the SIR; all are more mature versions of previous submittals.

JPL gate products: JPL requires a few first-time submittals at SIR, including a Preliminary Mission Operations Assurance Plan, and a number of updates to earlier documents, such as a Final Flight System Integration and Test Plan.

Gate products are artifacts. Most take the form of documents, such as plans. Some take the form of review presentation materials. Some take the form of required online submittals. As was the case for previous reviews, there were instances (fortunately fewer than before) where authors needed assistance in understanding what exactly was required for a particular product; the RC provided interpretations, obtaining assistance when necessary from JPL's Project Support Office (PSO). The PSO was particularly helpful in identifying the JPL-required documents, which, in combination, are equivalent to the NASA-required Operations Handbook.

Those items requiring common GRAIL project formatting were formatted to a template generated by the Documentation Lead for the previous reviews. Authors were given the choice of using the templates and doing their own document creation, formatting, and submittal or else using the DL's staff to convert their working versions into properly formatted and submitted gate products. Once draft versions were submitted, they were either routed for review, if applicable, or put into the signature cycle, if signatures were required. (Some products did not require project-internal review because of how they were generated, e.g., the Significant Risk List was created during the project's pre-SIR Risk Board meeting; revisions to requirements documents were reviewed and approved via Configuration Control Board action.) Products were submitted to a project repository established by the Project Librarian. After signatures were obtained, the Librarian uploaded a copy to the SRB's repository so that the SRB could perform its "documentation review."

Several rows and columns from the actual GRAIL SIR tracking tool are provided as Figure 3. For more information on the gate products methodology, see the previous IEEE papers, which go into significantly more detail (e.g., summarizing the features of the project's tracking tool for gate products).

7. PRESENTATION MATERIALS

Presentation planning needs to begin well in advance of the SIR. As with previous reviews, the team employed a three-step process: Outline Review, Dry Run, and Final Slides.

The Outline Review frames the review presentation package. Presenters do not bring in draft text slides, but instead present a simple outline of the topics they will cover, the key messages, and any issues, concerns, and risks. For the spacecraft subsystems, the Review Captain and Flight System Manager prescribed a chart-by-chart outline, so presenters were asked only to describe their open paper status (more on this below) and to identify their issues, concerns, and risks. Some presenters had planned to talk about multiple small issues, some about one significant issue, and some no issues at all; additionally, some of the issues slated for discussion at the subsystem level were already covered at the flight system level. Our approach was, wherever practical, to discuss an issue/concern/risk only once at the SIR. At the Outline Review, without looking at specific language, the review team was able to identify quickly any missing topics, unnecessary subjects, or material best handled by another presenter. The resulting puts and takes enabled the team to revise the proposed review agenda, especially the time allocations.

In pre-NPR 7120 days at JPL, the SIR was known as the Assembly, Test, and Launch Operations (ATLO) Readiness Review and could be completed in a day or, at most, 1.5 days. Its purpose was to determine, simply, whether the project was ready to start flight system integration and test. With the addition of NPR 7120.5D- and NPR 7123.1-required topics (and prerequisite gate products, not all of which were relevant to initiating integration and test)—converting what formerly was a technical review into a combined technical/schedule/cost review—this became a 3-day event.

The SIR top-level agenda, as refined, was as follows:

Day 1: Project Status, covering science and science implementation, project management, project systems engineering, project V&V, safety and mission assurance, business management, compliance status, and flight system.

Day 2: Hardware Status, including spacecraft system, eight spacecraft hardware subsystem reports, software, payload, ATLO management, and a tour of the in-process flight hardware and facilities.

Day 3: ATLO Readiness, with system test infrastructure, ATLO operations, mechanical ground-support equipment (GSE), ATLO test flow, system test lab and simulators, ATLO GDS, electrical GSE, ATLO readiness, launch system, mission design, MOS/GDS, and project summary.

Seq Number		PRODUCTS	KEY LIFE-CYCLE MILESTONES				Assigned to	Due Date	Status	Comments
			MDR/PMSR	PDR	Proj/Sys CDR	SIR				
Nominal timing is shown. Projects with system contracts may need to prepare documents required for the RFP earlier, as appropriate.										
		Project Systems Engineering								
PSE	**1**	Planetary Protection Category letter	NASA approval requested			<resubmit>	Lehman ©		SIGNED	Completed at PDR or earlier, but needed re-submit due to new NASA Category for lunar missions (new UN Treaty).
PSE	**2**	Project Level 2 Requirements	Preliminary	Final			Gounley ©	NA	<completed at CDR or earlier>	Title is Project Requirements Document. Updated version from DOORS
PSE	**3**	Project library & MCDL established	Operational				Reiz ©	NA	<completed at PDR or earlier>	
PSE	**4**	Project Verification & Validation results					NA	NA	NA	Not due until after SIR
PSE	**5**	Inter-system (flight-ground) interfaces		Draft ICDs	Final ICDs		Gounley ©	NA	<completed at CDR or earlier>	Title is Flight-Ground Interface Control Document
		EEIS Phased Development & Test Plan				<final>	Lock ©		SIGNED	Title is Preliminary EEIS Phased Development and Test Plan
		EEIS Concept					Lock ©	NA	<completed at CDR or earlier>	
PSE	**6**	Significant Risk List	Preliminary	Baseline		<updated>	Price ©		SUBMITTED May Risk Board version, updated with June Board version	
		Project Risk List				<updated>	Price ©		SUBMITTED May Risk Board version, updated with June Board version	
PSE	**7**	Probabilistic Risk Assessment (for Category I and Risk Class A projects only)		Initial PRA	Updated PRA		NA	NA	NA	GRAIL is not Cat. 1 or Class A
PSE	**8**	Functional FMECA (Risk Class A projects only)		Preliminary	Final		NA	NA	NA	GRAIL is not Cat. 1 or Class A
PSE	**9**	Orbital Debris Compliance Assessment	Initial	Preliminary	Final		Ratliff ©	NA	<completed at CDR or earlier>	Title is Orbital Debris Assessment Report
		End of Mission Plan					Ratliff ©	NA	<completed at CDR or earlier>	

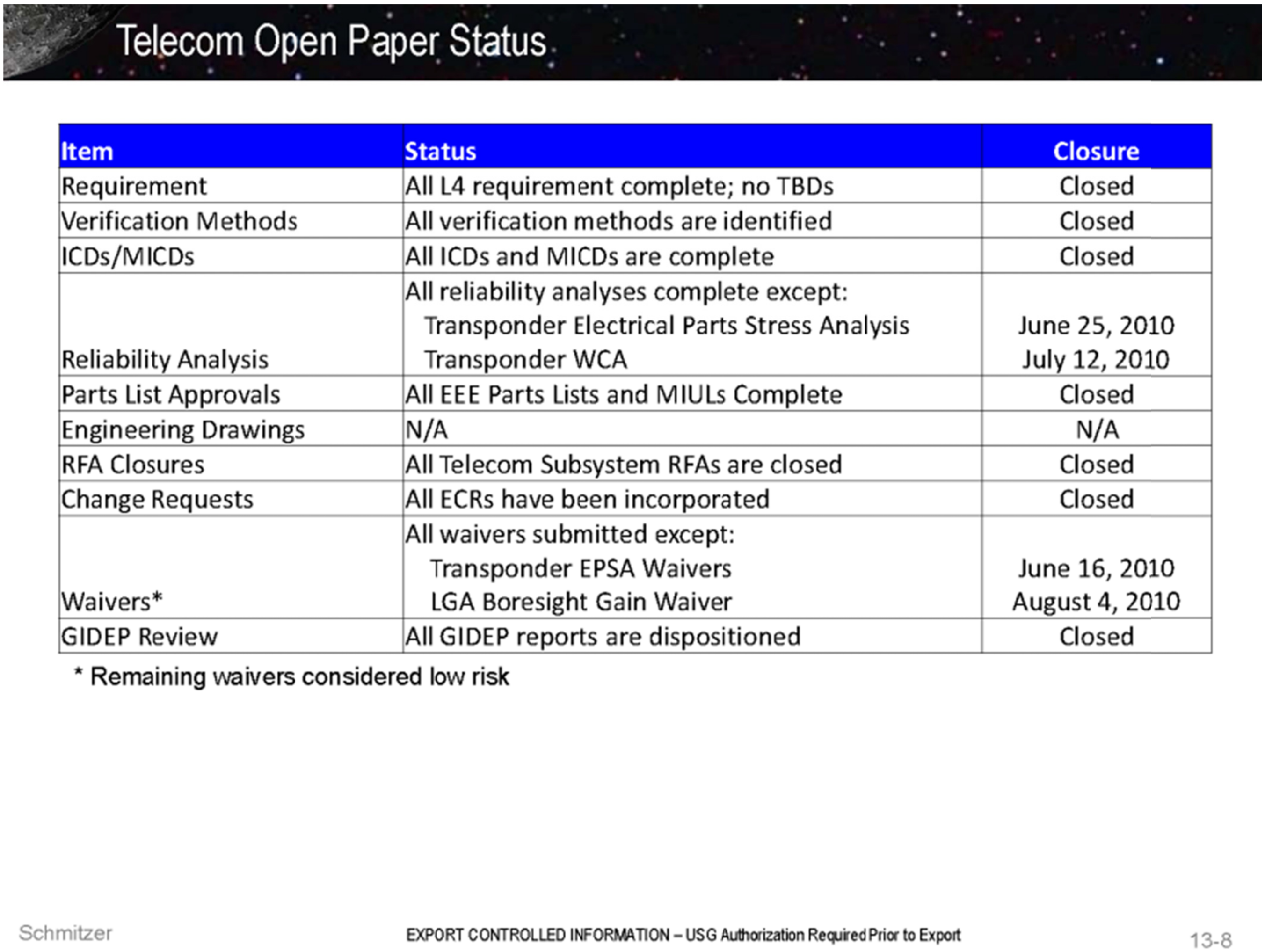
Figure 3—GRAIL SIR Gate Products Tracking Tool

A Dry Run was scheduled two weeks before the actual SIR. Advance instructions, including a slide template set, supported the presenters. The set included templates for title slide, agenda slide, generic slides for text-only, text-with-tables, and text-with-graphics, open paper, and issues and concerns. The open paper slide was new and particularly effective, as it enabled the audience to see on a single page the completion status of all documents required of the subsystem in order to begin ATLO. Any required paper that was not complete necessitated supporting text explaining what the problem was and how it would be worked off prior to its actual ATLO need date. A sample open paper slide is shown in Figure 4.

The Dry Run was conducted at LM Denver as a flip-through of the slides on a compressed schedule, with the presenter asked to verbalize his/her key message for the majority of slides, and to verbalize his/her full presentation on specific slides, generally sensitive/ controversial topics but in some cases complex material that was hard to convey succinctly to reviewers who were not experts in the field. The Dry Run was scheduled for three days, but only 2.5 were needed. On the other hand, a few presenters were directed to come back on "Do-over Day" to re-present their material, focusing on how they had incorporated changes requested by the mock review board.

Final Slides preparation was smoother than for previous life-cycle reviews. With respect to export control, the Review Captain determined whether each JPL presentation was controlled or uncontrolled, and the LM Program Manager did the same for LM presentations, both having received corporate training in this activity. As for the formatting and content of the presentations, the presenters were given a deadline for submission; then the Review Captain reviewed all of the slides (detecting content problems, e.g., errors, ambiguities, and placement of material in the presentation proper or in backup, as well as major formatting problems, e.g., illegibility, confusing flow of slides) and provided advisory corrections to the authors. The authors then modified their presentations as they deemed appropriate and submitted final versions to the Documentation Lead for production.

The production schedule was not nearly as frantic as for previous reviews. Authors required little assistance in using the presentation format, which was virtually identical to that used for CDR. More importantly, the Review Captain had



Item	Status	Closure
Requirement	All L4 requirement complete; no TBDs	Closed
Verification Methods	All verification methods are identified	Closed
ICDs/MICDs	All ICDs and MICDs are complete	Closed
Reliability Analysis	All reliability analyses complete except: Transponder Electrical Parts Stress Analysis Transponder WCA	 June 25, 2010 July 12, 2010
Parts List Approvals	All EEE Parts Lists and MIULs Complete	Closed
Engineering Drawings	N/A	N/A
RFA Closures	All Telecom Subsystem RFAs are closed	Closed
Change Requests	All ECRs have been incorporated	Closed
Waivers*	All waivers submitted except: Transponder EPSA Waivers LGA Boresight Gain Waiver	 June 16, 2010 August 4, 2010
GIDEP Review	All GIDEP reports are dispositioned	Closed

Figure 4—GRAIL SIR Open Paper Status Slide

negotiated an agreement with the SRB Chair to hold a "bookless" SIR. Electronic versions of the presentations were submitted to the SRB's repository in advance of the review, as before, but no hard-copy books were printed, proofed, corrected, and shipped, saving several days.

8. Information Technology and Logistics

Logistics and IT concerns remained important for this review because the review would take place at Lockheed Martin (the spacecraft provider), but participants would include MIT, JPL, GSFC, KSC, ULA, NASA Headquarters, and the NASA Program Office at MSFC, as well as the SRB. The LM Logistics Lead managed the attendance list and on-site access approvals (working with the Visitor Center representative), and interfaced with the LM IT lead.

A policy was established to somewhat limit in-person attendance, principally to presenters, mandatory support personnel, the SRB, and NASA oversight personnel. Presenters' team members were strongly encouraged to participate remotely, as discussed further below. Obtaining approval for Foreign Persons (FPs) to come on-site at LM was not straightforward, so because none of the FPs working on GRAIL were essential to this review, they were excluded from the in-person and remote attendance lists.

Finding a suitable conference room at LM proved no simple problem. The most suitable presentation room was already booked by another NASA project for its Project PDR. (GRAIL had booked the room for one week later, then accelerated its SIR because it would be ready earlier than originally projected and also to avoid the short July 4 holiday week.) A scouting trip was made to a conference room in the building next door, but it was too small and as a classified building had unacceptable limitations on wireless and cell phone connectivity. A third, more distant location was identified, and a reconnaissance visit determined that it was large enough, contained the necessary breakout rooms, and had ample parking. Its disadvantages were the lack of videoconferencing equipment and its distance from the lunchtime cafeteria. Nonetheless, the room was accepted, with remote-access via audio line and access to the slides via a "Meeting Place" capability or from the project's electronic library repository. Buses took attendees to and from the central cafeteria (the nearest public facilities being far from the LM plant).

The LM IT lead ensured audio and Meeting Place availability throughout the review. She had participated in the Dry Run, one day of which was intentionally held in the SIR conference room in order to identify any idiosyncrasies early enough to resolve them before the review. A setup team, including the Review Captain, Logistics Lead, and IT Lead, supported by a few others, staged the conference room the Friday before the Monday review. This included final test-out of the IT equipment, arranging assigned seating, equipping the breakout rooms, and setting up display items (posters and spacecraft models).

Because of the thorough advance work, there were no major logistics and IT problems during the three days of the review. As an area of improvement for future reviews, special measures need to be taken to ensure that from the first hour of the review there is effective Internet connectivity for the participants.

9. SRB COORDINATION

SRB coordination continued to improve between Project CDR and SIR. In part this was because of increased familiarity and trust. The board recognized that the project had made a good faith effort to respond to the Recommendations for Action (RFAs) from Project PDR and CDR. Some RFA closures were not initially accepted by the SRB, so, as agreed, the SRB issued some delta-RFAs, and the project's closures of all these were accepted. The SRB Chair had been copied on the project's monthly status report to senior NASA and JPL management, so she was aware of the key progress and problems after the Project CDR. The main concern of the board, the incomplete status of the flight avionics design, was addressed by having several SRB members participate in the project's Avionics Delta-CDR, which was successfully passed a month after Project CDR. Additionally, the SRB participated in many of the pre-SIR reviews (see Section 5), including one, the MOS Staffing Peer Review, that the SRB had specifically commissioned.

The SIR agenda had been negotiated with the SRB, ensuring that during the review itself, the project team was attentive to the SRB's areas of concern. Two supplemental presentations were prepared and delivered during the review: one on reaction wheel status (the sole major technical problem at SIR, due to a failure in test during the preceding ten days), and one on avionics schedule status (to demonstrate multiple contingency options available to maintain ATLO schedule despite late delivery of outstanding electronic parts). The SRB asked some additional questions on these and other topics, which the project worked on overnight and briefed the following morning. The Chair commended the project for the quality and responsiveness of the walk-on presentations.

A continuing area of difficulty involved the independent schedule assessment process. The process for performing this activity was new to NASA and had proven problematic at Project PDR and Project CDR. The project, the SRB chair, the SRB cost/schedule consultants, and NASA Independent Program Assessment Office all agreed that there was great room for improvement. Many meetings and telecons were held prior to the SIR; terms of engagement were not fully agreed upon, but deliverables acceptable to the project were submitted. A splinter session on cost and schedule questions was conducted during the SIR. Despite everyone's best intentions and best efforts, the differences in methodology (how JPL as an institution does scheduling versus how the SRB's NASA and consultant personnel perform it) were not fully reconciled. In the end, the SRB generated a qualitative schedule assessment only, with all parties recognizing that the use of parametric schedule risk models as late in project development as the SIR was not likely to produce meaningful results. On the positive side, the employment of Earned Value Management data to support schedule analysis was noncontroversial, and its implications were accepted by all.

Another notable aspect of SRB coordination included regular conference calls among the SRB (Chair and Review Manager), project (Project Manager, Review Captain, and Business Manager), NASA Headquarters (Program Executive), and NASA Program Office (Mission Manager). These were very positive and very useful in making sure everything that needed to be done was in fact done. Negotiations of the GRAIL Terms of Reference (ToR) Addendum for SIR had no notable problems.

10. RECOMMENDATIONS AND FUTURE APPLICATIONS

The NPR 7120.5D independent life-cycle reviews construct is maturing, but the actual implementation by the SRB, particularly the introduction of changed cost and schedule assessments and a new requirement for a quick "one-pager" report from the SRB to the Decision Authority, require flexibility on the part of the project as well as the SRB and oversight personnel. Changes in approach may or may not be intrinsically desirable to the project team, but in either case they can be quite disruptive if occurring in the run-up to the major review (i.e., while people are dedicated to pre-SIR reviews, gate products, and review presentation materials).

Project leadership can take several actions to minimize distractions and use life-cycle reviews to move the project forward.

(1) Suit up a review preparation team early. Make certain that roles are clear and that necessary support is acquired. Suit up a Logistics Lead at the location where the review will be held.

(2) Hold early and regular review planning telecons with the SRB Chair and Review Manager and the NASA Program Executive (and NASA Mission Manager, if applicable).

(3) Generate and maintain a review preparation schedule, integrated with the project development schedule (a just-in-time approach).

(4) Begin dialogue early about how the SRB will assess cost and schedule. Document the agreements in the ToR. Include cost- and schedule-related project deliverables and corresponding deadlines.

(5) Define SRB members' participation in pre-SIR project reviews, including protocols (e.g., a member of the review board, or not a member of the instant review but an observer who can contribute comments and RFAs).

(6) Agree on a series of pre-SIR document deliveries commensurate with the project development schedule, covering cost/schedule products, pre-SIR reviews materials and review board reports, and gate products. Include an understanding that those gate products likely to be significantly impacted by the pre-SIR reviews will be delivered later. Implement a disciplined gate products generation and review tracking system under a designated project lead.

(7) Identify SRB members' major "care-abouts" from the pre-SIR reviews and other interactions and make sure they are reflected in the top-level agenda negotiated with the SRB. Assign each area of concern to specific presenters. Early in Day 1 of the SIR, indicate what the areas of concern are and when and how they will be addressed.

(8) Adjust the SIR agenda, and instructions to presenters, to reflect the SIR's nature as a hardware review.

(9) Don't allow personnel to get by with redlining their Project CDR slides: The SRB will be impressed with the design but not convinced that you are ready to start flight system integration and test.

(10) Focus on demonstrating maturity of hardware, software, and documentation. Demonstrate clearly that documentation is largely completed and that remaining open paper will be closed on a credible schedule to support ATLO needs. Using this approach, the project can in effect write some of the SRB's review findings for them.

11. SUMMARY

The GRAIL Project established and effectively utilized a review preparation team for its Project SIR. They and the project team completed all necessary pre-SIR reviews, gate products, presentation materials, IT and logistics activities, and SRB coordination, for a successful SIR [12, 13].

REFERENCES

[1] Gravity Recovery And Interior Laboratory (GRAIL) Mission Proposal, June 2007, p. D-1.

[2] GRAIL Mission Proposal, p. D-1.

[3] GRAIL Mission Proposal, p. D-2.

[4] NM 7120-81, NPR 7120.5D, "NASA Space Flight Program and Project Management Requirements," NASA Interim Directive (NID) for NASA Procedural Requirements (NPR) 7120.5D, September 22, 2009, Table 2-7.

[5] NPR 7123.1A, "NASA Systems Engineering Processes and Requirements," March 26, 2007, Appendix G.10.

[6] "Institutional Project Review Plan" (IPRP), Rev. 4, JPL Rules! DocID 75512, June 25, 2010.

[7] "Required Products at JPL Project Life Cycle Transition Gates," Rev. 8, JPL Rules! DocID 60052, March 18, 2009.

[8] R. L. Taylor, "Reducing NPR 7120.5D to Practice: Preparing for a Life-cycle Review," IEEEAC paper #1531, Version 3, Updated January 5, 2009.

[9] R. L. Taylor, "Reducing NPR 7120.5D to Practice: Preparing for a Remote Site Life-cycle Review," IEEEAC paper #1291, Version 1, Updated October 20, 2009.

[10] IPRP, p. 55.

[11] NPR 7123.1A, ibid.

[12] For more technical information on GRAIL, see T.L. Hoffman, "GRAIL: Gravity Mapping the Moon, Aerospace Conference, 2009 IEEE ()978-1-4244-2622-5), 7-14 March 2009.

[13] The author acknowledges the invaluable assistance of the GRAIL SIR preparation team: Angus McMechen, Logistics Lead; Claire Marie-Peterson, Documentation Lead; Julie Reiz, Information Systems Lead; Leslie Bennett, Site Information Systems Lead; Suzanne Sinclair, Project Librarian; Edward Bennett, Configuration Management Engineer; their support teams; and the JPL Project Support Office. The author also thanks Dr. Maria T. Zuber, PI, and David Lehman, PM, for the continuing opportunity to work on the GRAIL project.

BIOGRAPHY

Randall Taylor *is the Project Acquisition Manager and Review Captain for the Gravity Recovery And Interior Laboratory (GRAIL) robotic lunar mission study. He also serves as Project Manager of the JPL Acquisition Reengineering Project. He was the Project Acquisition Manager for the Prometheus Project at JPL, which was developing a revolutionary new development nuclear electric propulsion (NEP) spacecraft for deep space exploration. Prometheus utilized a unique co-design approach to spacecraft development by JPL, the Department of Energy Office of Naval Reactors, Northrop Grumman, and five other NASA Centers. He served as Procurement Manager for the Mars Pathfinder Project, which successfully landed the first rover on Mars. In his 29 years at JPL, other key assignments have included contract negotiator for Deep Space Network 34-meter antennas in the U.S., Australia, and Spain, and supervisory and management positions responsible for flight project procurement personnel. He has negotiated contracts with Russian and Swedish organizations and supported international agreements and subcontracts with German, Danish, and Italian organizations. He served on the NASA Program Management Council Working Group (PMCWG), which wrote NASA Policy Guidelines (NPG) 7120.5A and .5B, the NASA Integrated Action Team (NIAT), and the NPR 7120.5D Team. He received B.A. and J.D. degrees from UCLA, is a member of the State Bar of California, and is a Certified Professional Contracts Manager.*